GaN epitaxial growth using RF pulsed laser deposition (PLD) method with molten Ga target

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Gallium Nitride (GaN) is a very promising semiconductor which has a direct band gap of 3.4eV at room temperature. Owing to violet-emission capability and related outstanding properties, GaN has attracted much attention from researching and industrial fields. So far, GaN thin films have commonly been grown by metal organic chemical vapor deposition (MOCVD) and molecular beam epitaxy (MBE).

The pulsed laser deposition (PLD) method is of much interest toward the formation of nitride-compound films including GaN. The PLD is characterized by the cleanness due to the external heat source and by the adequate energy of ablated species arriving at the substrate surface. However, almost no detail concerning either the Ga ablation or the GaN epitaxy has been reported yet.

In this study, from both the physical and engineering interests, we set the ArF excimer laser PLD system up equipping the rf-pumped N-radical beam source and ultrahigh-speed framing streak camera to observe the basic dynamics of ablated Ga atoms and environmental nitrogen species. Our interest was placed on examinations to what extent we can precisely control the GaN thin film growth and on determination of the relationship between the GaN crystallinity and ablated-particle kinetics. The grown GaN films were characterized by XRD, RHEED, Raman scattering, CL, EPMA, AFM, and familiar electrical and optical measurement way.

As to the growth rate of GaN on the sapphire substrate, we had **0.003 nm/shot** when the laser fluence was 2.9 J/cm^2. This suggests that the PLD will allow us to design and produce the sophisticated layer-structure of the GaN family. So far, we had (0002) XRD peak with FWHM as low as **0.16 degree** that is fully acceptable for the practical use. A typical example of the RHEED pattern of PLD-grown GaN homoepitaxy is given in Fig.1, showing pretty nice crystallinity.

Figure 2 shows the streak photographs of the Ga plume taken at every 0.3 μs after departure from the target surface. Curve-fitting of the plume intensity profile indicates that the velocity distribution of emitted Ga particles is briefly expressed by the shifted center-of-mass Maxwell distribution. The relation between the kinetic energy of Ga atom and the laser fluence is summarized in Table I. <u>A new finding is that the kinetic energy of Ga atom remains almost</u>

unchanged (～29 eV) against the change of the laser fluence. The change of the laser fluence only influence the number density of ablated Ga atom. This characteristic facilitates automated kinetic energy control of the flying Ga atoms anytime we do the growth experiment under the various conditions, e.g. from high to low (no less than the threshold) laser fluence ranges. However, the energy value itself stands at the very critical one that may or may not bring some damage into the film during the growth via impinging. Actually, we overcame this obstacle by adopting the **off-axis PLD method**.

At the workshop, we will disclose details on the growth technology, characterization of both the electrical and the optical properties of GaN films, and close relationship between the crystallinity and the Ga atom kinetics.

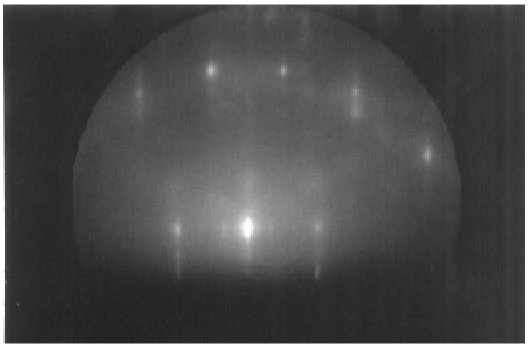

Fig.1. $(11\bar{2}0)$ RHEED pattern of GaN thin film deposited on epitaxial GaN/Al_2O_3 substrate.

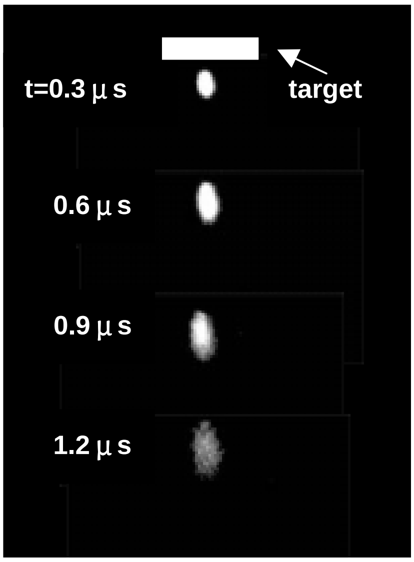

Fig. 2. The streak photograph of the emission plume from Ga atoms in vacuum. The laser fluence was $2.9 J/cm^2$.

Table I The flow velocity u_m ($\times 10^6$ cm/s) dependence on laser fluence and time.

Laser fluence	t=0.6 μs	0.9 μs	1.2 μs
$2.6 J/cm^2$	u_m=0.9	0.9	0.9
$2.9 J/cm^2$	0.8	0.8	0.8
$3.1 J/cm^2$	0.9	0.9	0.9